

INVESTIGATION OF LASER TREATED STEEL SURFACE

József Hlinka ^{1*}, Zoltán Weltsch ^{1,2}

¹ Department of Automotive Technologies, Faculty of Transportation Engineering and Vehicle Engineering, Budapest University of Technology and Economics, Hungary

² John von Neumann University, Faculty of Engineering and Computer Science, Department of Materials Technology, Hungary

Keywords:

laser treatment
solder paste
soldering
steel
wettability

Article history:

Beérkezett: 17 September 2017

Átdolgozva: 18 October 2017

Elfogadva: 14 November 2017

Abstract

The article aims to discuss the effect of surface treatment on the wettability between DC01 steel and SAC305 lead-free solder paste. The industrial applications of laser technologies are increasing constantly. A specific laser treatment can modify the surface energy of steel and affect the wetting properties. The surfaces of steel plates were treated by Nd:YAG laser with different laser powers. After the laser surface treatment wetting experiments were performed between the steel plates and lead-free solder paste. The effect of laser treatment on steel surface microstructure was analyzed by optical microscopy. The experimental results showed that the wetting contact angles do not change up to 700 W laser power.

1 Introduction

Soldering is the most popular joint technique in microelectronic and optoelectronic industries which technologies are widely used in the vehicle industry [1, 2]. Soldering is the process of joining two metals by the use of a solder alloy, and it is one of the oldest known joining techniques. In the soldering process, the molten solder wets the metal and reacts with a small amount of the base metal by forming intermetallic compounds. Therefore, the wetting property between solders and substrates is crucial to the reliability of the soldering joints [3].

An important task for both engineers and scientists to achieve that the components surface properties are appropriate to their function. During the past years, a number of researches have clarified the effects of the laser irradiation on different material surfaces, such as metals, semiconductors, polymers and multilayer materials. Previous works found that the laser surface treatments of copper lead to wettability changes [4, 5]. Lawrence et al. [6-8] found that the wettability of carbon steel, alumina/silica-based oxide could be improved by high power diode laser irradiation and the changes of the wettability was attributed to three aspects: surface oxygen content; surface roughness; surface microstructure. They also found that the phase change and the increase in crystal size could lead to the changes of surface energy.

This work experimentally determines the wetting property changes and microstructure changes in DC01 steel following the Nd:YAG laser treatment.

2 Materials and methods

The investigations were carried out on DC01 steel plates. This type of steel is widely used for cold forming and other applications. The plates were sectioned into 15 x 15 mm squares. Before the laser treatments the steel plates were grinded and polished to remove the oxide layer and reach similar surface properties in every sample and washed with 96 % ethanol (C₂H₆O).

The laser used in the study was Rofin DY 027, Nd:YAG pulsed laser with emission of 1064 nm wavelength laser beam (Figure 1.). The laser beam (TEM₀₀) was focused directly onto a 0.4 mm

* Corresponding author. Tel.: +36 30 482 7169
E-mail address: jozsef.hlinka@gt.bme.hu

diameter spot on the surface of steel plate. During the laser surface treating process, the laser beam was traversed across the steel samples by means of a laser scanner at speed of 500 mm/s. The laser scanning speed must be controlled properly to ensure that a 40 x 40 mm square (4 samples) area can be treated by laser. Different laser powers, from 100 W to 1000 W, were used in this process. The laser was used in continuous wave. Argon gas was used as shielding gas to protect the samples from oxidation during laser irradiation with the flow-rate of 12.5 l/min.

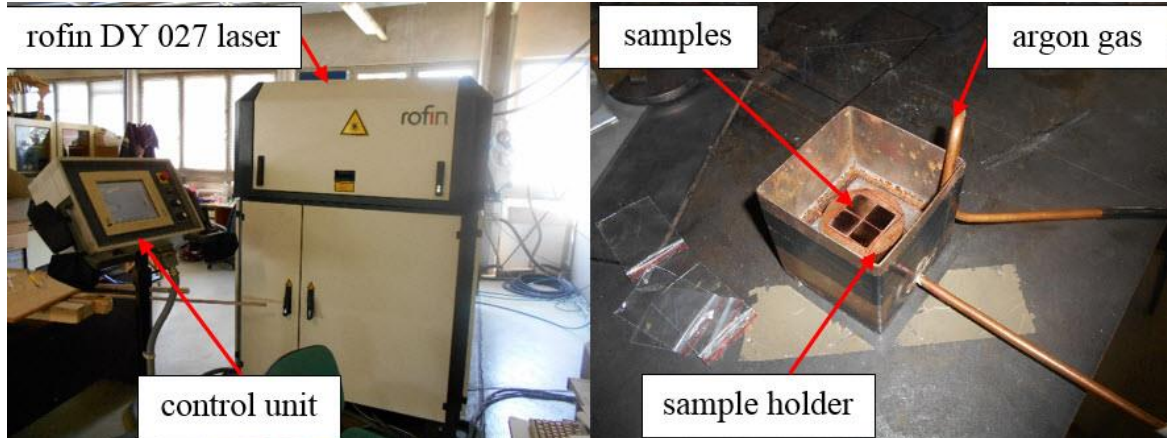


Figure 1. Rofin DY 027, Nd:YAG pulsed laser and working space with the samples

The wetting experiments were performed in a wetting angle measuring system (Figure 2.) which can measure the wettability using sessile drop method [9], taking the methodological issues summarized by Sobczak [10] into account.

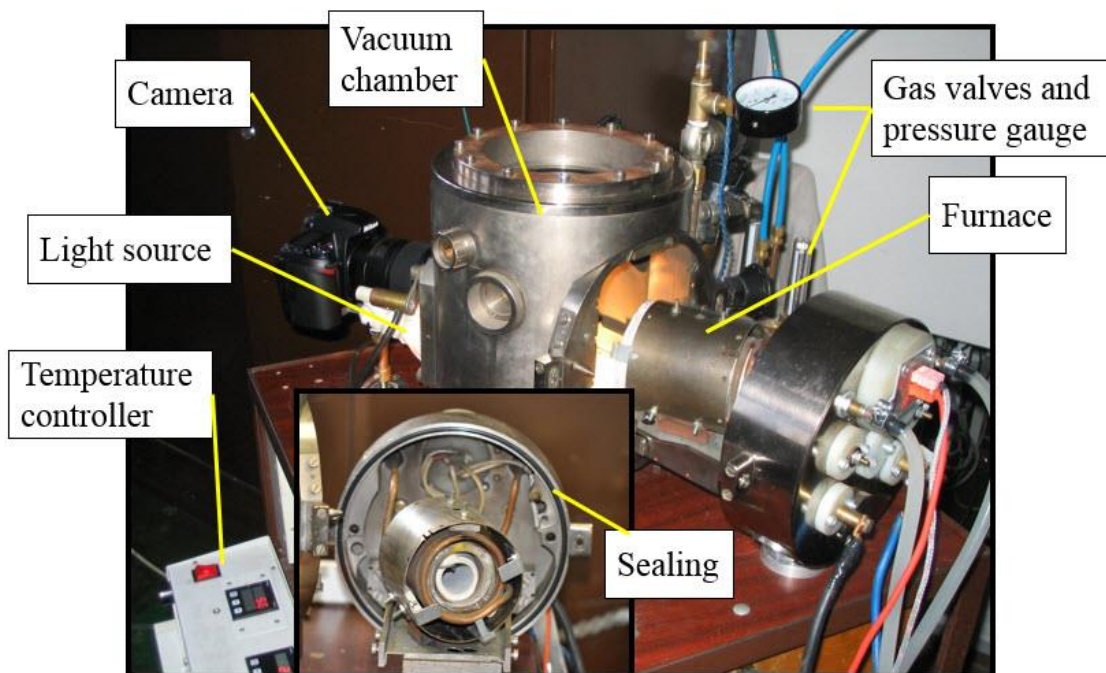


Figure 2. Wetting angle measuring equipment

The measurements can be performed in air or inert atmosphere. The heat required for the measurements provided by a resistance-heated tube furnace which can ensure the measuring temperature up to 1473 K. In this paper the measuring temperature was not high, the melting temperature of investigated solder are below 523 K.

At the beginning of the wetting angle measurements the samples were positioned into the furnace at ambient conditions. The measurements were performed in air atmosphere. Thereafter the

temperature was raised up to the measuring temperature. The contact angle values of the drop were measured directly from its images. The total uncertainty of the measured values was $\pm 0.75^\circ$.

In order to analyse the influence of the laser treatment on microstructure, the specimens, before and after laser treatment, were sectioned with a cutting machine using a diamond-rimmed cutting blade. The sectioned specimens were mounted with methyl-methacrylate casting resin then, subsequently, grinded with SiC grinding paper and polished with diamond suspension down to $1\ \mu\text{m}$. The steel surface were examined on the cross sectioned samples by optical microscope.

3 Results and discussions

The solder paste is a mixture which contains solder alloy powder and flux. The storage time and storage conditions have effect on the usability of the solder. The flux contains some volatile components and if these components evaporate the paste becomes worse and for example not suitable for stencil printing.

To get some information about the effect of holding time on the wettability between the SAC305 solder [11] and DC01 steel three different pastes were examined. The three paste conditions are fresh solder paste, old solder paste (older than the double shelf life time) and old solder paste diluted with another flux (to balance the drying of the paste). The wettability measurements were made on grinded, polished and untreated DC01 substrates. Figure 3. shows the results of 9 different measurements with each solder paste.

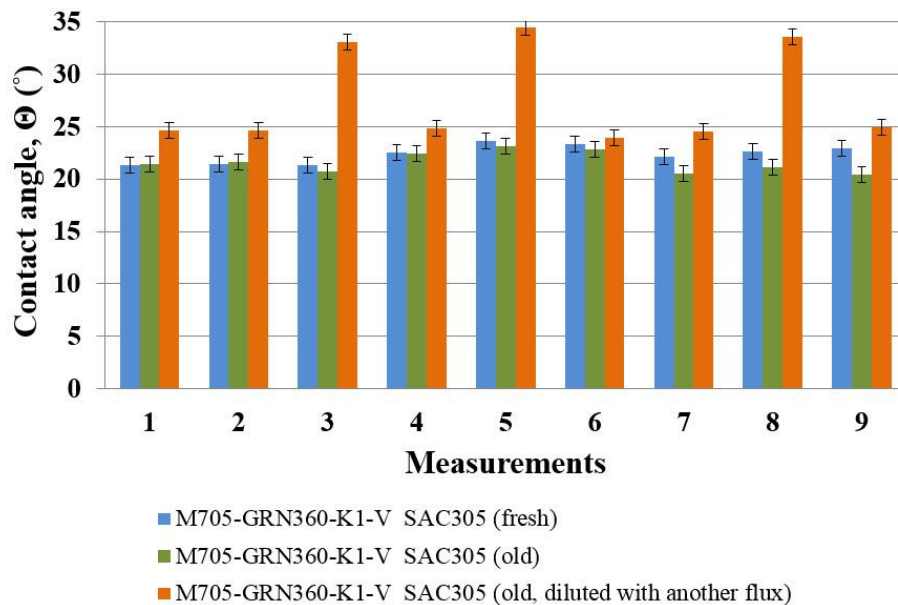


Figure 3. Measured contact angles of 3 different SAC305 solder paste and DC01 steel

The results show that the fresh solder paste and the old solder paste do not show differences between the wettability. The contact angles are higher, when the old solder paste used which diluted with another flux. Based on the results we can say that in our measurement system the age of the measured solder paste are not affect the wettability, if it is fresher than the double shelf life of the paste.

Figure 4. presents a visual inspection on the wettability characteristics of Sn–Ag–Cu solder on the DC01 steel substrate after laser surface irradiation. In case of the wettability measurements there were 3 measurements and on figure 4. the average of the 3 measurements and the differences are shown for each laser power level.

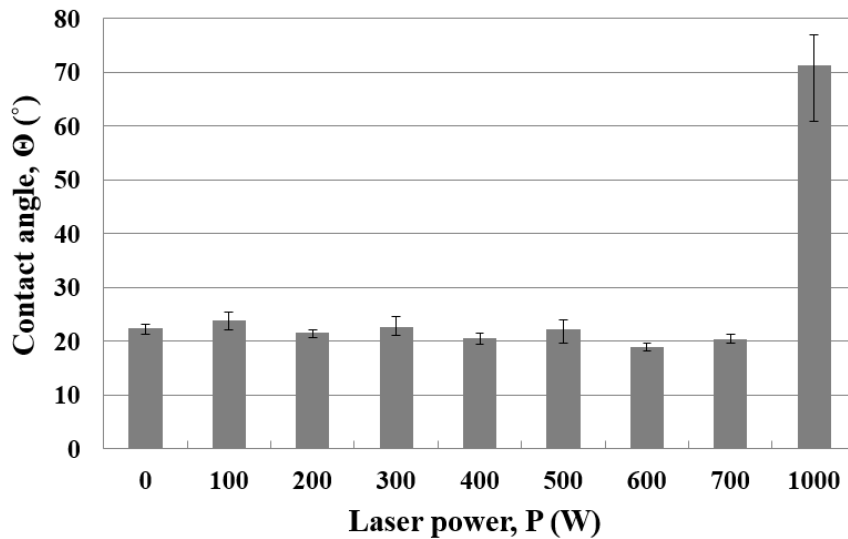


Figure 4. Measured contact angles of laser treated DC01 steel and SAC305 solder paste

The graph shows that the contact angles do not change definite when the steel plates treated with up to 700 W laser power. If the laser power was 1000 W the contact angles increased. On the surface of the treated samples there is no optically determinable change up to 700 W. Surface roughness measurements verify this statement. There is no difference between the surface roughness of the treated surfaces up to 700 W laser power. The measured average roughness of the samples up to 700 W laser power was R_a 0.05 μm . In case of the 1000 W laser power treatment the surface of the polished steel was optically visibly changed. The measured surface roughness of this sample was R_a 0.11 μm .

The surface layer microstructures of the optical metallographic samples are shown in Figure 5. As may be seen by comparing Figure 5(a, b, c) the laser treatment cause noticeable change on the steel surface layer when the laser power was 1000 W.

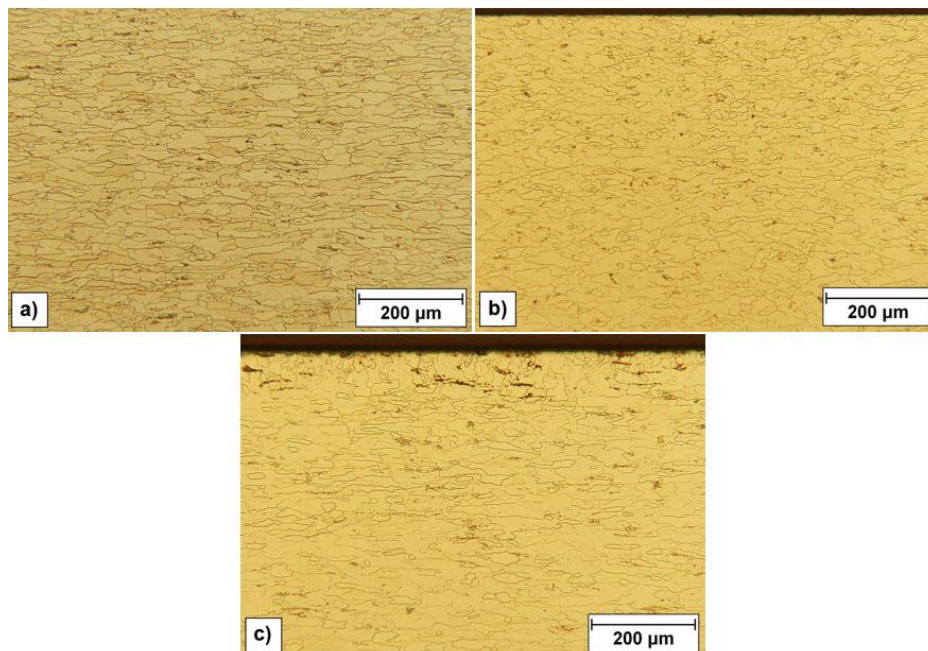


Figure 5. Optical microphotographs of the surface layer microstructures of DC01 steel: a) without laser treatment, b) after laser irradiation with 600 W laser power, c) after laser irradiation with 1000 W laser power

The observations indicate that when the laser power was 600 W, the heat absorbed by the steel could not lead to change of the microstructure. The microstructure is look like a cold rolled steel structure. The microstructure near to the surface layer was changed, when the laser power was 1000 W. The modified thickness was $\sim 90 \mu\text{m}$.

4 Conclusion

In summary, the effect of the pulsed Nd:YAG laser irradiation on the wettability and the microstructure of DC01 steel plate was investigated in this paper. It was found that using a laser power of 0 W to 700 W the wettability between the steel and the solder paste do not change, namely there were no significant changes in the measured contact angles. When the laser power was 1000 W the contact angle became higher. The microstructure was influenced by the laser treatment when the laser power was 1000 W.

Acknowledgment



Supported by the ÚNKP-17-3 New National Excellence Program of the Ministry of Human Capacities.

References

- [1] M. Judd and K. Brindley, *Soldering in Electronics Assembly*, Oxford, Newnes, 1999.
- [2] K. N. Tu, *Solder Joint Technology: Materials, Properties, and Reliability*, New York, Springer, 2007.
- [3] F. G. Yost, F. M. Hosking and D. R. Frear, *The Mechanics of Solder Alloy Wetting and Spreading*, New York, Van Nostrand Reinhold, 1993.
- [4] Z. Zhao, C. Wang, M. Li, L. Wang, and L. Kong, "The effects of pulsed Nd:YAG laser irradiation on surface energy of copper," *Applied Surface Science*, Vol. 252, pp. 4257–4263., 2006.
- [5] J. Hlinka, M. Berczeli, G. Buza and Z. Weltsch, "Wetting properties of Nd:YAG laser treated copper by SAC solders," *Soldering & Surface Mount Technology*, Vol. 29 Issue: 2, pp. 69-74, 2017. DOI 10.1108/SSMT-01-2016-0003.
- [6] J. Lawrence and L. Li, *Laser Modification of the Wettability Characteristics of Engineering Materials*, UK, Professional Engineering Publishing Limited, London and Bury St Edmunds, 2001.
- [7] J. Lawrence and L. Li, "Wettability characteristics of a modified mild steel with CO₂, Nd:YAG, excimer and high power diode lasers," *Journal of Physics D: Applied Physics*, Vol. 32, pp. 2311-2318, 1999.
- [8] L. Hao and J. Lawrence, "CO₂ laser induced microstructure features in magnesia partially stabilised zirconia bioceramic and effects thereof on the wettability characteristics," *Materials Science and Engineering*, Vol. A 364, pp. 171–181, 2004.
- [9] M. Abtew and G. Selvaduray, "Lead-free Solders in Microelectronics," *Materials and Science Engineering Reports*, Vol. 27, pp. 95–141., 2000.
- [10] N. Sobczak, M. Singh, and R. Asthana, "High-temperature wettability measurements in metal/ceramic systems – some methodological issues," *Current Opinion in Solid State and Materials Science*, Vol. 9, pp. 241–253., 2005.
- [11] Technical Bulletin M705-GRN360-K [Online]. Available: <http://www.senju.com/images/pdf/2011-M705-GRN360-K.pdf>. [Accessed: 31-Mar-2016].